5.0 Board Signatures

Date: 2/11/2000

S. David Stadler
DOE Accident Investigation Board Chairperson
U.S. Department of Energy
Office of Environment, Safety and Health

Date: 2/11/2000

Chip Lagdon
DOE Accident Investigation Board Member
U.S. Department of Energy
Office of Environment, Safety and Health

Date: 2/11/2000

William E. Miller
DOE Accident Investigation Board Member
U.S. Department of Energy
Office of Environment, Safety and Health

Date: 2/11/2000

Bruce Breslau
DOE Accident Investigation Board Member
U.S. Department of Energy
Office of Environment, Safety and Health

Date: 2/11/2000

Pete O'Connell
DOE Accident Investigation Board Member
U.S. Department of Energy
Office of Environment, Safety and Health

6.0 Board Members, Advisors, and Staff

Chairperson	S. David Stadler, DOE**,** Office of Oversight
Member	Bruce Breslau, DOE, Environment, Safety and Health
Member	Chip Lagdon, DOE, Office of Oversight
Member	William E. Miller, DOE, Office of Oversight
Member	Pete O'Connell, DOE, Environment, Safety and Health
Advisors	Mohammed Mozumder, DOE, Office of Defense Programs Mark Good, Paragon Technical Services, Inc. Bernie Kokenge, Paragon Technical Services, Inc. Jim Lockridge, Paragon Technical Services, Inc. Thomas McSweeney, Battelle Columbus Ed Stafford, Paragon Technical Services, Inc.
Medical Advisor	Joseph Falco, M.D., Brookhaven National Laboratory
Analytical Support	Jeff Oakley, Battelle Columbus
Technical Writer	Thomas Davis, Paragon Technical Services, Inc.
Administrative Support	Barbie Harshman, DOE, Office of Oversight Lee Roginski, Paragon Technical Services, Inc. Marcia Taylor, Battelle Columbus Kathy Moore, Battelle Columbus Michelle Stover, Battelle Columbus

APPENDIX A
BOARD APPOINTMENT MEMORANDUM

EH2-013907

Department of Energy
Washington, DC 20585

December 10, 1999

MEMORANDUM FOR: G. LEAH DEVER, MANAGER
OAK RIDGE OPERATIONS OFFICE

FROM: DAVID MICHAELS, PhD, MPH
ASSISTANT SECRETARY
ENVIRONMENT, SAFETY AND HEALTH

SUBJECT: Investigation of the December 8, 1999, Chemical Explosion at the Y-12 Plant, Oak Ridge, Tennessee

I hereby establish a Type A Accident Investigation Board to investigate the December 8, 1999, Chemical Explosion at the Y-12 Plant. I have determined that it meets the requirements for a Type A investigation consistent with DOE Order 225.1A, *Accident Investigations*.

My office will lead the investigation, with the Board chaired by a member of my management staff. I appoint Dr. S. David Stadler, Acting Deputy Assistant Secretary for Oversight, as the Accident Investigation Board Chairperson. The Board will be composed of the following members: Chip Lagdon, ES&H Evaluations; William Miller, ES&H Evaluations; Pete O'Connell, Worker Protection Programs and Hazards Management; and Bruce Breslau, ES&H Evaluations. A representative from the Office of Defense Programs will also be designated to serve on the Accident Investigation Board. The Board will be assisted in the investigation by advisors and other personnel as deemed necessary by the Board Chairperson.

The scope of the Board's investigation will include, but not be limited to, analyzing causal factors, identifying root causes resulting in the accident, and determining Judgements of Need to prevent recurrence. The investigation will be conducted in accordance with DOE Order 225.1A. The investigation and analyses will be conducted within the framework of the Department's Integrated Safety Management Policy to assure maximum benefit to improving safety and sharing lessons learned throughout the complex.

The Board will provide my office with periodic reports on the status and progress of the investigation. These reports should not include any findings or arrive at any premature conclusions until an analysis of all the causal factors has been completed. Discussions of the investigation and copies of the draft report will be controlled until I accept and authorize release of the final report. The final report should be provided to my office by February 18, 2000.

cc: T. Gioconda, DP-1
D. Stadler, EH-2
J. Fitzgerald, EH-5
C. Huntoon, EM-1
W. Magwood, NE-1
R. Poe, OR
J. Mullins, OR AI POC

APPENDIX B
APPLICATION OF ANALYSIS METHODS AND TOOLS

B-1. Causal Factors Analysis

A complete causal factors analysis was performed to evaluate the causal factors of the accident, including the direct cause, root causes, and contributing causes. The analytical techniques that were used were events and causal factors charting and analysis, barrier analysis, and change analysis. The **direct cause** of the incident is the immediate events or conditions that caused the accident. **Root causes** are the causal factors that, if corrected, would prevent recurrence of this and similar incidents. **Contributing causes** are other events and conditions that collectively with other causes increased the likelihood of an accident but individually did not cause the accident.

The **direct cause** of the explosion and resulting injuries was the disturbance (impact with a steel probe) of an unrecognized and unanalyzed shock-sensitive explosive compound (consisting of potassium superoxide and mineral oil) that was formed when mineral oil was inappropriately sprayed on a previous NaK spill.

Section 3 of the report presents the analysis of the various safety-related processes and systems and identifies the contributing causes of the accident. Root cause analysis of these contributing causes rolls them up to higher-level root causes, which are listed, along with a short discussion of each, in Table B-1. Figure B-1 shows the contributing causes and most-directly-related root causes. Figure B-2 shows an events and causal factors chart for this accident.

B-2. Barrier Analysis

Barrier analysis identifies three types of barriers associated with the accident: (a) administrative barriers, (b) management barriers, and (c) physical barriers. A barrier is defined as anything that is used to control, prevent, or impede process or physical energy flows and that is intended to protect a person or object from hazards. Barriers that either failed or were missing led to the accident. Successful performance by any of these barriers would have prevented or mitigated the severity of the accident. The barriers that failed are summarized in Table B-2.

B-3. Change Analysis

Change analysis identifies changes or differences that might have affected the accident. These were analyzed to determine whether the change or difference might have contributed to the accident. The results of this analysis are shown in Table B-3.

Table B-1. Root Cause Analysis

Root Causes	Discussion
LMES failed to establish, seek, or maintain an adequate level of knowledge and competence on the hazards associated with NaK, including the formation of superoxide, the incompatibility of superoxide and organics, and the explosive sensitivity of the mixture to impact or shock.	There was an overall lack of technical competence and knowledge related to the interactive hazard involving NaK, superoxide, mineral oil, and shock or impact. There was also a failure to establish or maintain competence in the hazards associated with NaK through the available literature, technical expertise, or training. There was an overreliance on the skill of the craft and the knowledge of selected individuals and a reluctance to get additional expertise to help.
LMES's implementation of the hazard analysis and control processes failed to identify, prevent, or mitigate the explosive interaction of potassium superoxide, mineral oil, and impact. The NaK Material Safety Data Sheet was not used.	Many aspects of the hazard analysis and control process failed for both the December 1 spill and the December 8 explosion. No formal hazard analysis was performed for the spill recovery that led to the December 8 explosion, and MSDSs and other standard references were not utilized to identify the presence of superoxide and the importance of not adding mineral oil. There was a failure to comply with the NaK MSDS's warning on the formation of potassium superoxide and its incompatibility with organics. There was a failure to obtain the technical safety basis before spraying mineral oil onto an NaK spill containing potassium superoxide.
LMES management systems and processes did not assure adequate procedures or controls to prevent the loss of system configuration control resulting in an NaK spill or to preclude the addition of mineral oil and impact in the presence of potassium superoxide during NaK spill recovery.	Many processes and procedures were incorrectly implemented, not implemented, or incorrectly written. Procedures were not adequately categorized, verified, and validated; changes were not adequately controlled; and a "plan," which is not an authorized LMES mechanism, was used to control a hazardous work activity. Senior facility management was not adequately involved in the review and approval of procedures and revisions.
LMES management failed to effectively communicate or utilize information from the hazard screening evaluation, lessons learned, previous events and accidents, studies, analyses, and publications in planning and controlling this work and the associated hazards to worker health and safety. Knowledge of this hazard and expertise to address it were readily available at the Oak Ridge Reservation and other DOE sites.	Many textbooks, analyses, and previous accidents documented the explosive incompatibilities of potassium superoxide and organics. This information was not communicated or utilized by LMES in preparing the work activity or recovery plan. The 9720-27 hazard screening evaluation actually documented the superoxide-organic explosive interaction and shock sensitivity, but the information from Facility Safety Engineering was not communicated or effectively utilized by LMES management.
OR, YSO, and LMES have not established or assured a safety culture that implements an ISM process in which workers are consistently held accountable for adherence to procedures and hazard controls and are willing to stop work and seek management and technical assistance when procedures do not work or abnormal conditions are encountered.	The overall ISM system failed because DUO still was using expert-based systems (skill of the craft) instead of following ISM system procedures and control. Work should have been stopped, a hazard analysis performed, and management approval obtained when procedures did not work as written or when unusual conditions, such as a low NaK sump level or suspected superoxides, were encountered.

Table B-1. Root Cause Analysis (Continued)

Root Causes	Discussion
LMES's management systems and processes were not effective in assuring the provisions for and use of appropriate personal protective equipment for working with a pyrophoric liquid metal and protecting against thermal and caustic chemical burns and the inhalation of toxic and radioactive smoke.	Appropriate PPE that could have prevented or reduced the severity of the injuries, including thermal burns, chemical burns, and toxic chemical and radiological uptakes, is defined in LMES accident lessons-learned documents, OSHA requirements, and NaK MSDSs. The selection of PPE on the day of the accident or for other preliminary activities was not based on these requirements or on sound and documented analyses.

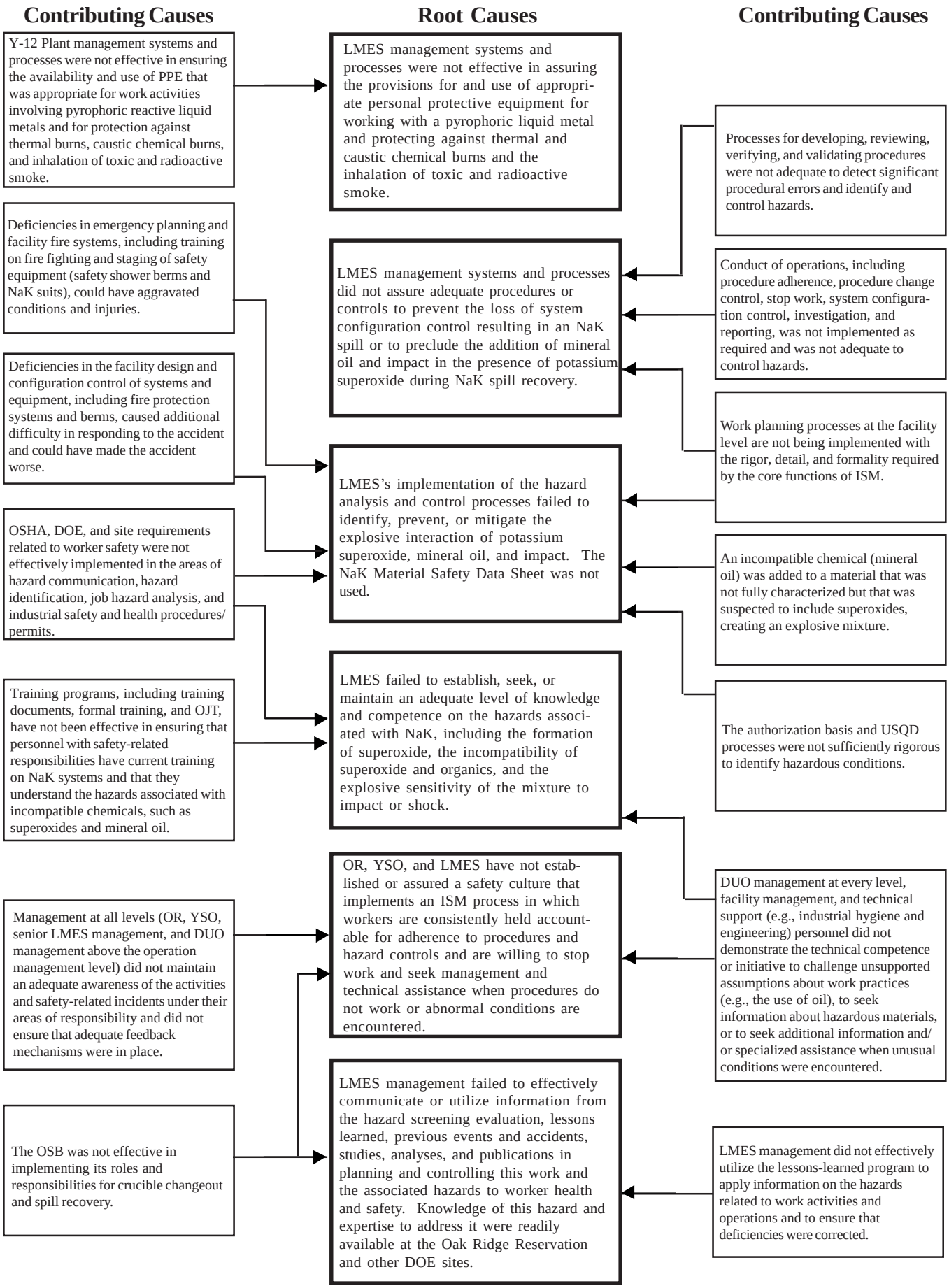


Figure B-1. Root and Contributing Causes

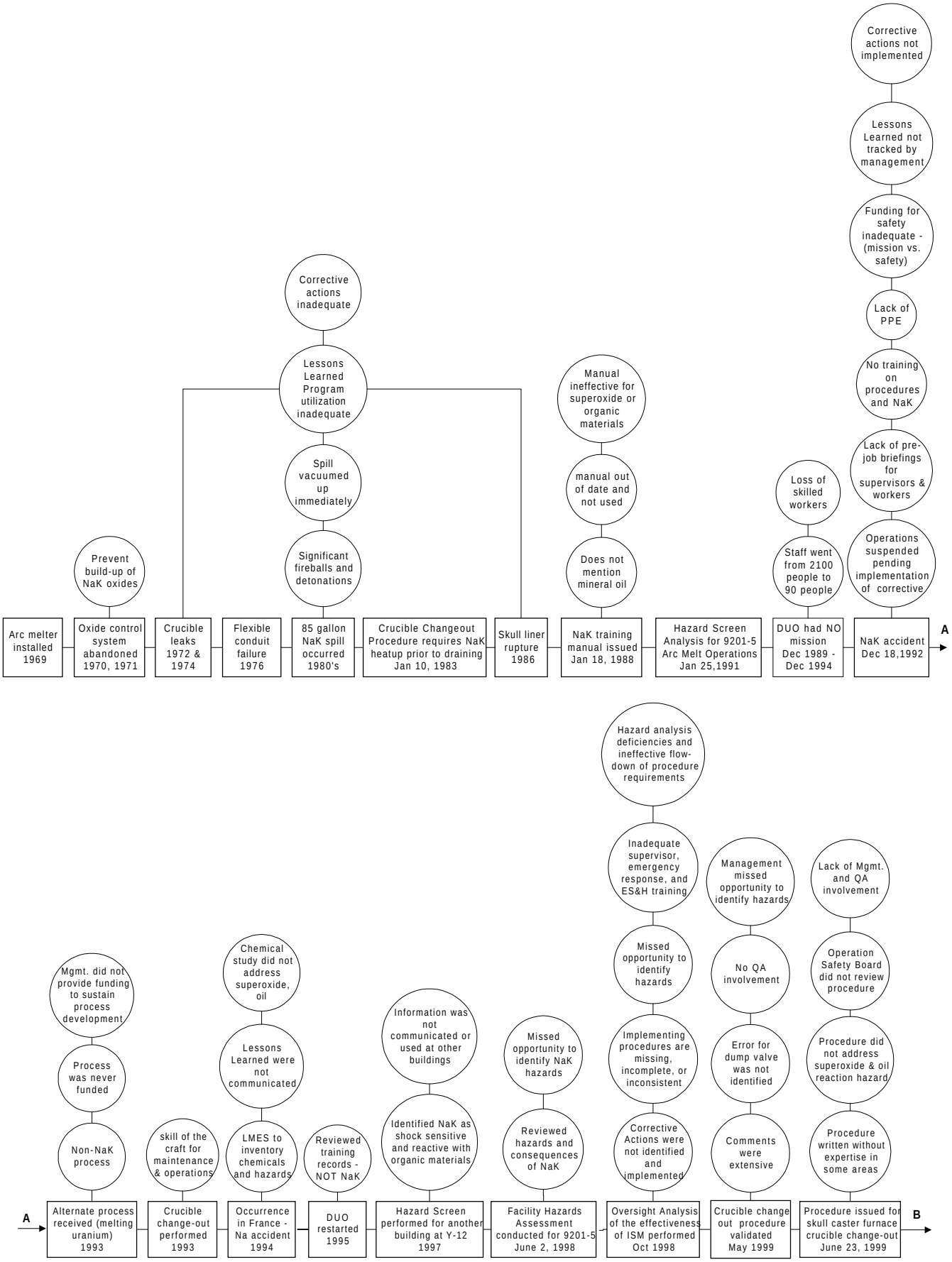


Figure B-2. Events and Causal Factors Chart

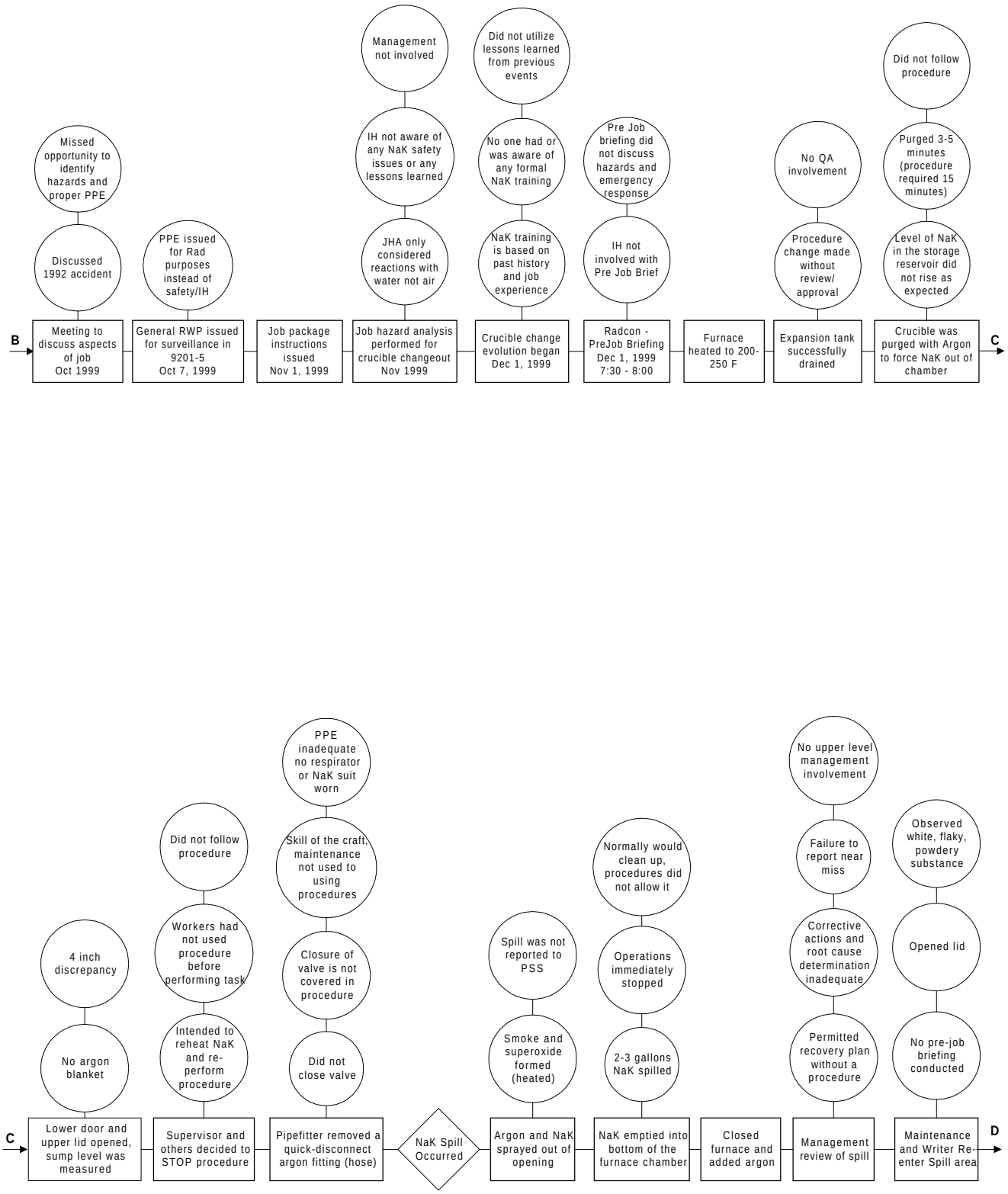
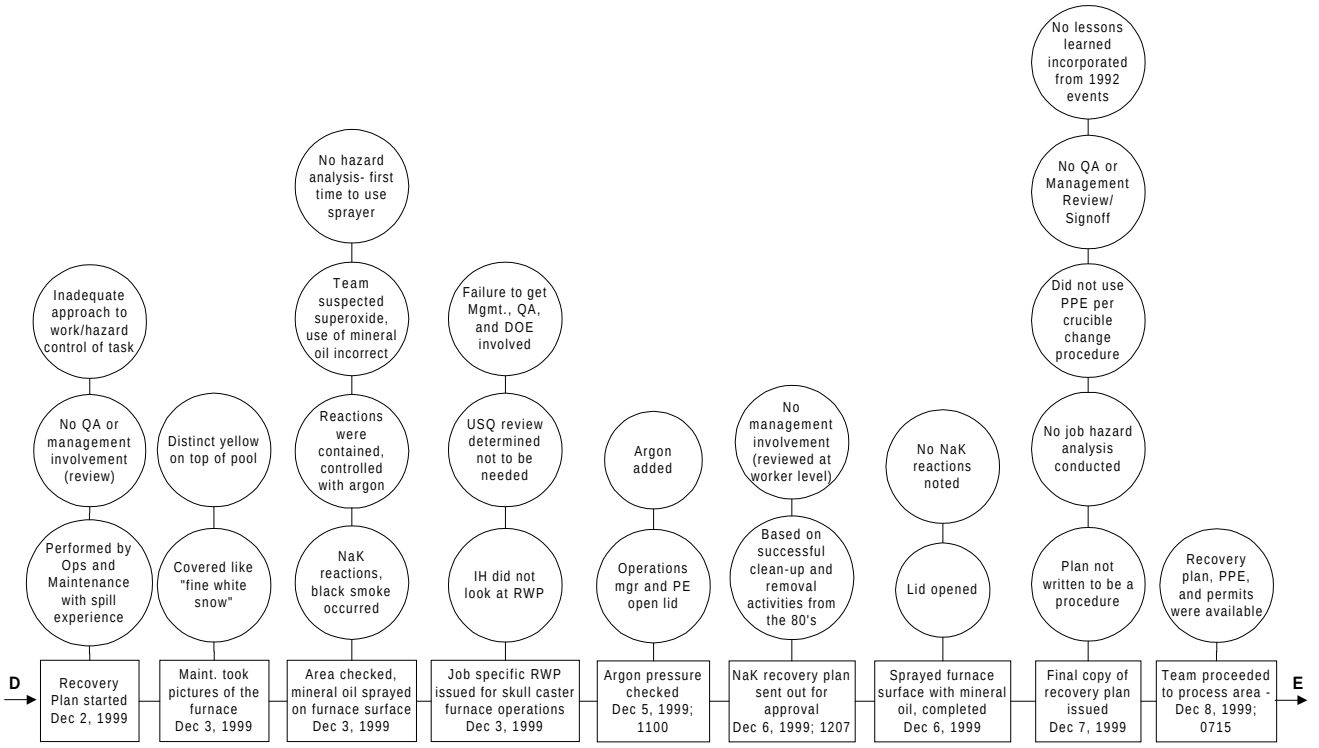


Figure B-2. Events and Causal Factors Chart (Continued)



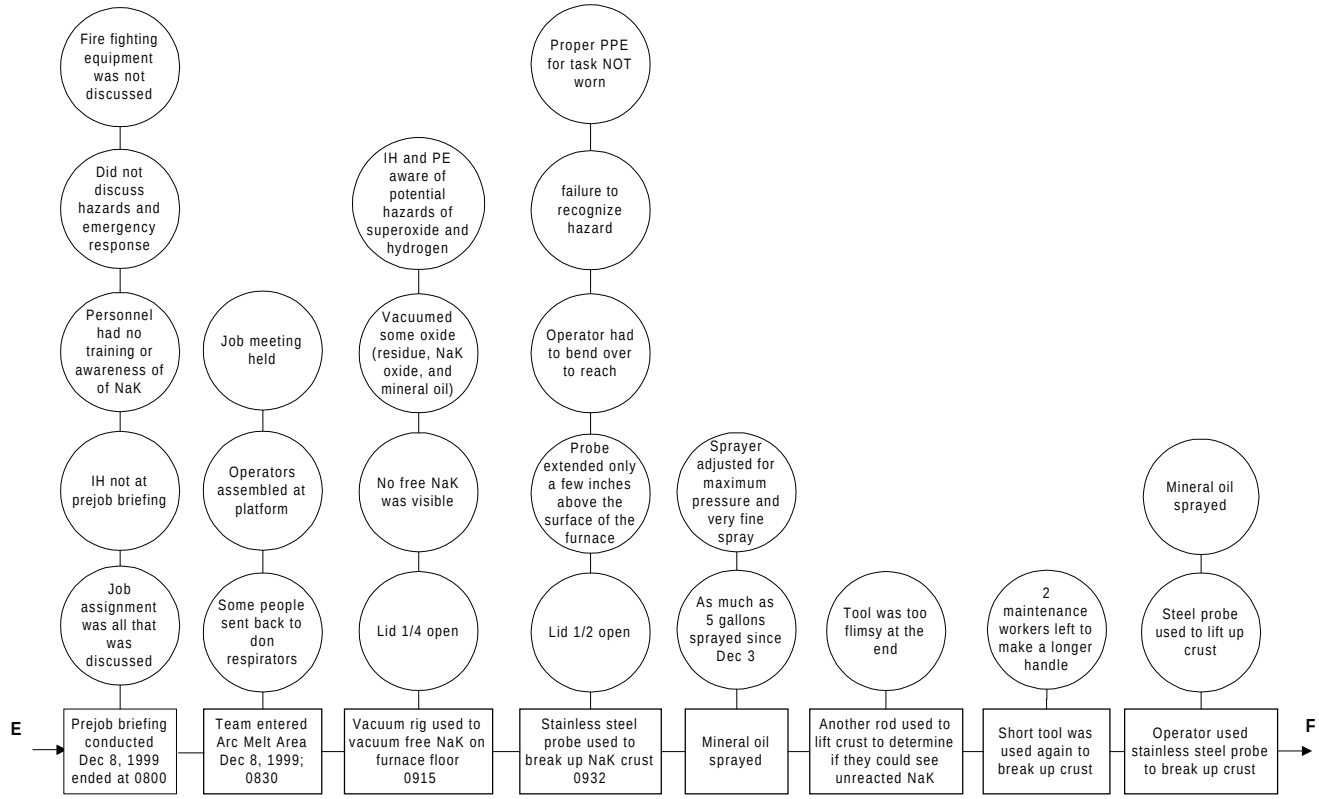


Figure B-2. Events and Causal Factors Chart (Continued)

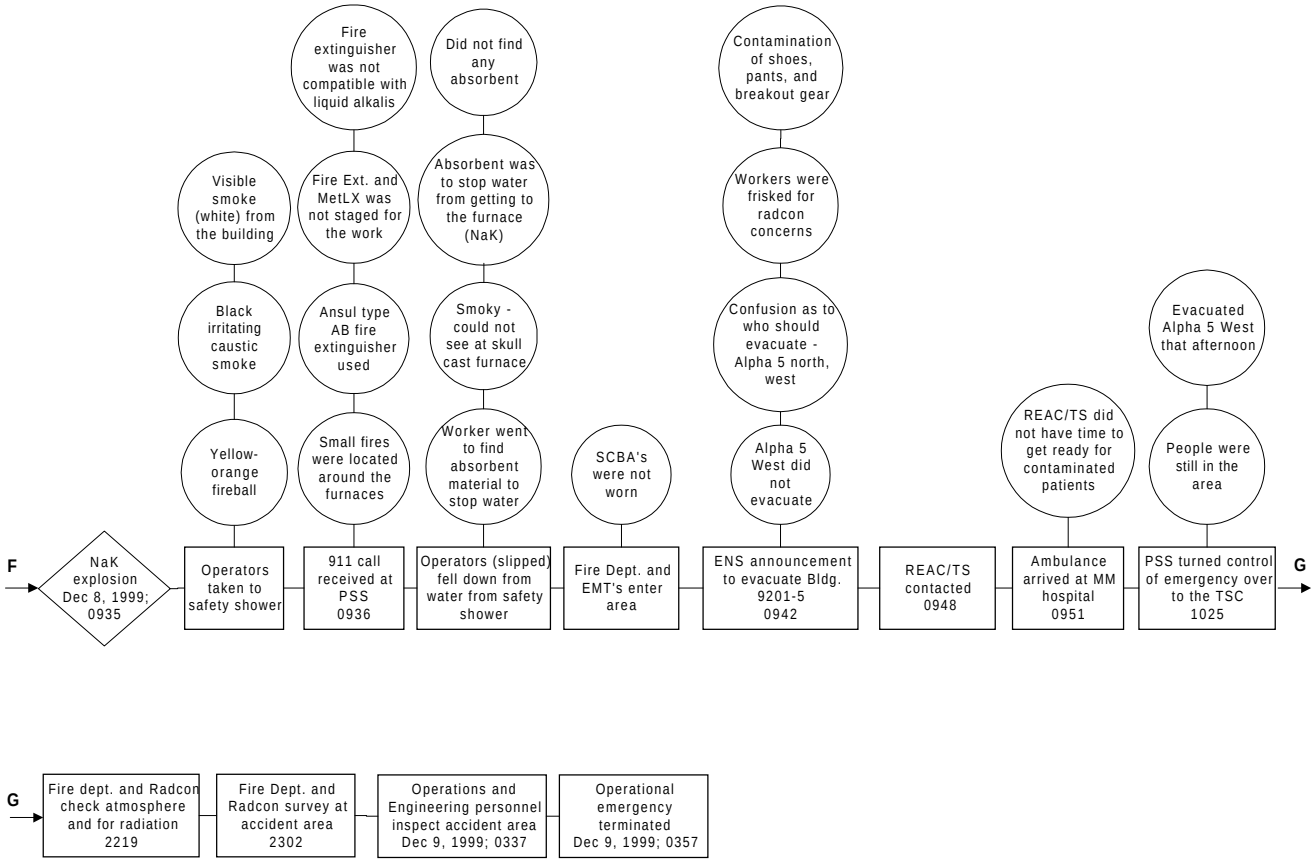


Figure B-2. Events and Causal Factors Chart (Continued)

Table B-2. Barrier Analysis Summary

Administrative	Pre-Job Briefing Procedures Procedure Verification and Validation ORPS/Accident Reporting Material Safety Data Sheets and Reference Documents Job Hazards Analysis Skill of the Craft
Management	Training Operational Safety Board Integrated Safety Management Process Lessons Learned/Corrective Actions Communication
Physical	Personal Protective Equipment Configuration Control – Oxide Control and Indication System Tools Anti-oxidation Material – Met-L-X vs. Mineral Oil NaK System Piping – Configuration Management

Table B-3. Change Analysis

Change or Difference		Analysis	
Planned/Normal	**Present**	**Difference**	**Analysis**
Maintenance workers perform maintenance activities while supervised by maintenance supervision.	Maintenance workers were performing operator functions and were supervised by operations.	Maintenance workers performed a task that was normally performed by an individual with expertise in operations. Maintenance work is not procedure driven.	Maintenance personnel are not adequately trained to be aware of the hazards of NaK or the requirements for following procedures. Maintenance personnel did not have the same level of training or experience in the identification and hazards of NaK or the equipment. Maintenance work usually involves expert-based routine work.
NaK is submerged in mineral oil. (According to reference books and the MSDS, this is for long-term storage and must not be used if superoxide is present.)	A fine spray of mineral oil was used on the NaK.	Mineral oil was sprayed on the NaK as a fine mist.	The use of mineral oil is not recommended for NaK and creates a shock-sensitive explosive when superoxides are present.
A clearly written recovery procedure is written for the cleanup work to be performed.	The activity was performed by use of an informal "recovery plan."	The level of review for the informal "recovery plan" is not as rigorous as for a procedure.	The informal "recovery plan" was not reviewed and validated, and not all hazards and emergency response actions were identified and mitigated. A formal job hazard analysis was not prepared.
PPE requirements for recovery specify an NaK suit for any work that has a potential to come in contact with NaK.	Workers wore only anti-contamination work coveralls.	Workers were not protected against the NaK.	The NaK suits could have reduced the seriousness of the burns caused by the explosion. *The procedures clearly state that an NaK suit should be worn.*
PPE requirements specify that flame-retardant coveralls be worn in the arc melter area.	Workers wore standard coveralls or lab coats.	Following the explosion, burning clothing caused some burns.	The required use of flame-retardant coveralls was dropped in the early 1990s for unknown reasons.
The crucible changeout procedure contains a detailed contingency plan for an NaK spill.	The procedure contained inadequate contingency plans and the spill was to be cleaned up seven days later. Mineral oil used to "slow" oxidation created an impact-sensitive explosive mixture.	The contingency plan in the procedure to clean up the NaK spill was inadequate. The spill was not cleaned up using the procedures recommended in the MSDS. The MSDS recommends immediate cleanup using Met-L-X or other powdered extinguishing agents.	No adequate spill contingency plan was written into the changeout procedure. The likelihood of an NaK leak or spill is fairly high, according to past experience.
Workers are adequately trained to perform NaK work.	Workers were not trained and did not understand that mineral oil and NaK creates a shock-sensitive mixture if superoxide is present.	Workers did not fully understand the hazards and chemistry of NaK.	There was an overall lack of training in and awareness of the hazards and chemistry of NaK and superoxide.
Job hazard analysis identifies hazards, and no oil is added.	No job hazard analysis was performed for the cleanup recovery work.	Not all appropriate hazards of the job were identified.	There was no formal job hazard analysis, and the informal analyses failed to identify the hazards associated with the superoxide, resulting in hazardous work being performed without appropriate PPE.
December 1 Spill (Major Changes)			
The skull caster furnace crucible changeout procedure is performed as written.	The procedure was validated and changed while work was being performed.	The procedure was incorrect and work continued to be performed. (See Section 3.2.)	This caused the December 1 spill.
The skull caster furnace crucible changeout procedure is followed step by step as required for a Category I procedure.	The procedure was classified as a Category III procedure.	The procedure was not followed step by step, and each step was not verified.	This caused the December 1 spill.

Tables, Figures, and Exhibits

Tables

Exhibits

Figures

Abbreviations Used in This Report

ACGIH	American Conference of Governmental Industrial Hygienists
BIO	Basis for Interim Operation
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulations
CO	Chemical Operator
DOE	U.S. Department of Energy
DNFSB	Defense Nuclear Facilities Safety Board
DP	Office of Defense Programs
DUO	Depleted Uranium Operations
EAP	Employee Assistance Program
EH	Office of Environment, Safety and Health
EOC	Emergency Operations Center
ES&H	Environment, Safety, and Health
FR	Facility Representative
FS	Front-line Supervisor
IDLH	Immediately Dangerous to Life or Health
IH	Industrial Hygienist
ISM	Integrated Safety Management
JHA	Job Hazard Analysis
LMES	Lockheed Martin Energy Systems
MSDS	Material Safety Data Sheet
NaK	Sodium Potassium Alloy
NIOSH	National Institute for Occupational Safety and Health
OCI	Oxide Control and Indication System
OJT	On-the-Job Training
OM	Operations Manager
OR	Oak Ridge Operations Office
ORMMC	Oak Ridge Methodist Medical Center
OSB	Operational Safety Board
OSHA	U.S. Occupational Safety and Health Administration
OSWP	Operations Safety Work Permit
PE	Process Engineer
PPE	Personal Protective Equipment
PS	Process Support Engineer
psi	Pounds per Square Inch
PSS	Plant Shift Superintendent
QA	Quality Assurance
RCT	Radiological Control Technician
REAC/TS	Radiation Emergency Assistance Center/Training Site
RWP	Radiological Work Permit
SAR	Safety Analysis Report
SCBA	Self-Contained Breathing Apparatus
TSC	Technical Support Center
USQ	Unreviewed Safety Question
USQD	Unreviewed Safety Question Determination
YSO	Y-12 Site Office